Table 2. Four-year summary of seed cotton yield in response to timing of sidedress nitrogen applications compared to soil and foliar N applications. 1982-1985. MAFES, Delta Branch, Stoneville, MS.

Trt. No.	Nitrogen (lb/A)[4/] PP	SD	FO	Seed cotton (lb/acre) 1982	1983	1984	1985	4-Year mean	% of[5/] standard
FIRST HARVEST									
1	0	0	0	2407 ab[1/]	2062 b[1/]	2191 b[1/]	2043 c[1/]	2176 c[2/]	78.6
2	40	0	40	2347 ab	2487 a	2806 a	3073 b	2678 b	96.7
3	80	0	0	2513 ab	2494 a	2960 a	3112 ab	2770 b	100.0
4*	40	40	0	2316 b	2454 a	2822 a	3070 b	2666 b	96.2
5**	40	40	0	2471 ab	2396 a	2893 a	3046 b	2702 b	97.5
6***	40	40	0	2570 a	2589 a	3047 a	3317 a	2881 a	104.0
	LSD (0.05)[3/]			233	313	330	296	139	
SECOND HARVEST									
1	0	0	0	413 b	222 c	250 c	148 c	258 c	64.2
2	40	0	40	694 a	323 b	340 bc	292 b	412 b	102.5
3	80	0	0	655 a	317 b	332 bc	303 b	402 b	100.0
4*	40	40	0	688 a	281 bc	367 b	275 b	403 b	100.0
5**	40	40	0	586 ab	284 bc	402 ab	317 b	397 b	98.8
6***	40	40	0	772 a	507 a	474 a	357 a	528 a	131.3
	LSD (0.05)[3/]			211	99	105	57	61	
TOTAL HARVEST									
1	0	0	0	2820 b	2284 c	2441 c	2191 c	2434 c	76.7
2	40	0	40	3041 ab	2810 ab	3146 b	3365 b	3090 b	97.4
3	80	0	0	3168 ab	2811 ab	3292 ab	3415 b	3172 b	100.0
4*	40	40	0	3004 ab	2735 b	3189 b	3345 b	3068 b	96.7
5**	40	40	0	3057 ab	2680 b	3295 ab	3363 b	3099 b	97.7
6***	40	40	0	3342 a	3096 a	3521 a	3674 a	3408 a	107.5
	LSD (0.05)[3/]			354	391	378	290	167	

Timing of sidedress: * Early (5/25/82, 6/09/83, 5/30/84, 5/28/85); ** Medium (6/23/82, 7/01/83, 6/13/84, 6/24/85); *** Late (7/13/82, 7/24/83, 7/06/84, 7/09/85).

1/ Mean of four replications. Means followed by the same letter are not significantly different at the 10% level by the Waller Duncan K-ratio T-test.
2/ Mean of four replications across four years (N = 16).
3/ LSD's are provided for mean comparisons at the 5% level of significance.
4/ Timing of application: PP = Preplant, SD = Sidedress, FO = Foliar.
5/ Standard: 100% Preplant (Trt. = 3).

Table 3. Four-year summary of percent first harvest cotton in response to timing of sidedress nitrogen applications compared to soil and foliar N applications. 1982-1985. MAFES, Delta Branch, Stoneville, MS.

Trt. No.	Nitrogen (lb/A)[4/] PP	SD	FO	Percent first harvest 1982	1983	1984	1985	4-Year mean
1	0	0	0	85.4 a[1/]	90.4 a[1/]	89.7 a[1/]	93.2 a[1/]	89.7 a[2/]
2	40	0	40	77.5 b	88.7 a	89.3 ab	91.3 ab	86.7 b
3	80	0	0	79.4 b	88.7 a	89.9 a	91.1 b	87.3 b
4*	40	40	0	77.4 b	89.7 a	88.5 ab	91.8 ab	86.9 b
5**	40	40	0	80.9 ab	89.4 a	87.9 ab	90.6 b	87.2 b
6***	40	40	0	76.9 b	83.6 b	86.8 b	90.3 b	84.4 c
	LSD (0.05)[3/]			5.2	2.4	2.5	2.0	1.5

Timing of sidedress: * Early (5/25/82, 6/09/83, 5/30/84, 5/28/85), ** Medium (6/23/82, 7/01/83, 6/13/84, 6/24/85), *** Late (7/13/82, 7/14/83, 7/06/84, 7/09/85).

1/ Mean of four replications. Means followed by the same letter are not significantly different at the 10% level by the Waller-Duncan K-ratio T-test.
2/ Means of four replications across four years (N = 16).
3/ LSD's are provided for mean comparisons at the 5% level of significance.
4/ Timing of application: PP = Preplant, SD = Sidedress, FO = Foliar.

GROWTH AND NUTRIENT UPTAKE OF COTTON AS AFFECTED BY N SOURCE AND DICYANDIAMIDE

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Key Words: DCD, Nitrification inhibitor, Urea, Ammonium-N, Nitrate-N

Abstract

The nitrification inhibitor dicyandiamide (DCD) offers potential for improving efficiency of N applications to cotton grown on sandy soils of the southeastern Coastal Plain. Research has indicated that cotton is sensitive to DCD. The purpose of this greenhouse experiment was to investigate the effect of DCD on growth and nutrient uptake of DPL 90 cotton grown for 73 days in pots containing a typical Coastal Plain soil (Norfolk sandy loam). Nitrogen (100 lb/ac equivalent) as $NaNO_3$ or urea, and DCD (0, 5, 10, 20, 30 and 40 lb/ac equivalent) were applied to the soil at first true leaf and plants were harvested 58 days later. Sodium nitrate increased leaf dry weight and total dry weight of plants 9.1 and 6.0%, respectively, over urea fertilized plants. DCD reduced linearly leaf area and dry weight and stem dry weight.

Fertilization with urea increased concentrations of leaf P, K, and Mn and reduced the concentration of Mg in leaf tissue. Dicyandiamide increased leaf N, P, and K concentrations but reduced concentrations of Ca, Mg, and Mn. Uptake rates (µg/g fresh root/day) of Ca and Mg were increased 7.5 and 13.7% respectively, with $NaNO_3$ vs. urea, while P uptake rate was 15.5% greater for urea fertilized plants vs. $NaNO_3$ fertilized plants. Dicyandiamide reduced Ca and Mg uptake rates. Phosphorus uptake rates were increased by DCD when urea was the N source. The effects of DCD on cotton growth and nutrient uptake generally resulted from the compound itself and were not an indirect result of nitrification inhibition. Although significant reductions in plant growth did not occur unless DCD exceeded that normally applied with recommended N rates on this soil, these results suggest a need for caution when applying DCD to cotton grown on sandy soils.

Introduction

Split applications of N are generally used to improve N efficiency of cotton grown on sandy soils of the southeastern Coastal Plain. The use of nitrification inhibitors such as dicyandiamide (DCD) with N applied at or near planting might preclude the need for split applications of N on these soils. Dicyandiamide is an effective nitrification inhibitor (Hauck, 1980; Rodgers and Ashworth, 1982) that has been shown to increase yields of winter wheat (Rodgers and Ashworth, 1982; Rodgers et al. 1985) and grain sorghum (Touchton and Reeves, 1985). Greenhouse tests involving DCD applications to cotton indicate that cotton is sensitive to DCD (Reddy, 1964; Reeves and Touchton, 1986). Field experiments in progress on a Norfolk sandy loam have shown erratic responses to preplant-banded applications of urea containing DCD (J. T. Touchton, 1986, personal communication). Averaged over 3 N rates (60, 90, and 120 lb/ac), urea formulated with 10% of the N as DCD-N reduced seed cotton yield 30% and 10%, respectively, in 2 years, but increased yield 13% in another year.

The reports of cotton's sensitivity to DCD, as well as yield reductions from ongoing field research, indicates a need for further research regarding DCD's effect on cotton. This investigation was designed to determine the effect of DCD on growth and nutrient uptake of cotton grown in a typical Coastal Plain soil.

Materials and Methods

Ten seeds of DPL 90 cotton were planted in separate 1.5 gal plastic containers containing 5.7 lb of Norfolk sandy loam soil. The initial soil pH was 5.8 and P, K, Ca, and Mg averaged 78, 152, 650, and 106 lb/ac, respectively. Organic matter content averaged 1.3% and CEC averaged 3.6 meq/100g. Ten days prior to planting seed, dolomitic limestone equivalent to 2200 lb/ac was mixed with the soil in each pot and each pot was watered to saturation. Pots were fertilized at planting, and weekly thereafter, with 2X Hoagland's solution minus N. At first true leaf (15 days after emergence) plants were thinned to 3 plants/pot and treatments were applied as aqueous solutions to the soil surface of each pot except 0-N check pots.

The experimental design was a factorial arrangement of N source X DCD rates in a randomized complete block with 5 replications. Nitrogen sources were urea and $NaNO_3$. Nitrogen rate (apart from DCD-N) was equivalent to 100 lb/ac. Dicyandiamide rates were equivalent to 0, 5, 10, 20, 30 and 40 lb/ac DCD-N (DCD contains 67% N).

Sixty-seven days after emergence (52 days after treatment initiation) plants were harvested and separated into leaves, squares and blooms, stems and roots. Roots were washed of soil, blotted dry, and weighed. Leaf area was determined and all plant organs were then dried for 72 h at 140°F and weighed. Squares and blooms were included with leaf tissue for analysis of Total-N, P, K, Ca, Mg, Fe, Mn, Zn and Cu.

Results and Discussion

Plant Growth and Phytotoxicity Symptoms

Nitrogen applied as $NaNO_3$ increased dry weight of cotton plants compared to fertilization with urea (Table 1). This increase was primarily a result of an increase in leaf tissue. The number of fruiting structures (squares + blooms) per plant was also increased by fertilization with $NaNO_3$ as compared to fertilization with urea. These results are similar to those reported from long term field experiments on a Norfolk sandy loam (Scarsbrook and Cope, 1958). On plots limed annually, the 10-yr average seed cotton yield of plots sidedressed with urea was 92% of that from plots sidedressed with $NaNO_3$.

Plant dry weight decreased linearly as DCD rate increased (Table 2). The decrease was due to reductions in both stem and leaf dry weights. Leaf area was reduced similarly to leaf dry weight (data not shown). Dicyandiamide reduced root fresh weight, but did not affect root dry weight. There were no DCD X N source interaction effects for any growth variable measured.

Six days after application of 30 or 40 lb DCD-N/ac cotton leaves developed mottled chlorosis. After 20 days mottled chlorosis developed on leaves of all plants treated with DCD. The chlorosis intensified with DCD-N rate, and progressed to necrosis with DCD-N rates > 20 lb/ac. Symptoms were similar for cotton treated with either N source.

Reductions in leaf-dry weight and foliar toxicity symptoms would suggest that the primary site of phytotoxicity of DCD is in leaf tissue and not root tissue. This would agree with data by Amberger and Vilsmeir (1983), reporting isolation of DCD taken up by oats and wheat in leaf and straw tissue rather than root tissue.

Nutrient Concentrations and Uptake Rates

The 100 lb/ac N rate and weekly fertilization with 2X Hoaglands solution proved inadequate for cotton grown in this soil volume under greenhouse conditions. Macronutrient concentrations of leaf tissue ranged below that generally considered to be sufficient (Table 3) (Sabbe and MacKenzie, 1973). Total-N content of entire plants was not affected by treatments, indicating that no appreciable uptake of mineralized DCD occurred. Apparent N recovery of N apart from DCD-N (N content of treated plants - N content of 0-N check plants) averaged 98% (data not shown).

Both N source and DCD affected leaf macronutrient concentrations (Table 3). Manganese was the only microelement affected by either N source or DCD. There were no significant interaction effects on concentrations of any nutrient element in leaf tissue.

Fertilization with urea increased concentrations of P, K, and Mn and reduced the concentration of Mg in leaf tissue (Table 3). The decreased growth resulting from urea fertilization would explain the increases in leaf P, K, and Mn concentrations.

In addition, NH_4^+-N uptake from urea would be expected to increase P concentration and reduce concentrations of Ca, Mg, and K (Sahrawat and Keeney, 1984). The inhibitory effect of NH_4^+-N uptake on K concentrations was diminished by reductions in growth. This accounts for the increased leaf K concentrations in plants fertilized with urea.

Dicyandiamide increased leaf tissue concentrations of N, P, K and lowered concentrations of Ca, Mg, and Mn (Table 3). Regression analysis indicated a linear relationship between DCD and concentrations of nutrient elements (analysis not shown). These relationships mirrored those of DCD on plant growth in that DCD effects were minimal until concentrations of DCD-N exceeded 10 lb/ac (the rate normally applied with 100 lb-N/ac). The increase in N, P, and K concentrations can be attributed to reductions in growth caused by DCD, however, decreases in Ca, Mg, and Mn concentrations cannot be attributed to growth reductions. There were no interaction effects on concentrations of any nutrient element in leaf tissue.

To isolate the effect of DCD on nutrient uptake from the confounding effect of plant growth, nutrient uptake rates were calculated. Calcium and Mg uptake rates were reduced by fertilization with urea (Table 4). This is in agreement with results demonstrating NH_4^+-N reducing Ca and Mg uptake (Sahrawat and Keeney, 1984).

Dicyandiamide reduced uptake rates of Ca and Mg (Table 4). The lack of any DCD X N source interactions suggests that reduced Ca and Mg uptake resulted from direct effects of DCD and not indirect effects caused by inhibition of nitrification and increased NH_4^+-N uptake.

Phosphorus uptake rates were higher with urea than $NaNO_3$ fertilization (Table 5). Dicyandiamide increased P uptake rates when urea was the N source. The effect is probably due to increased NH_4^+-N uptake from inhibition of nitrification as well as a direct effect of DCD, especially at rates > 20 lb DCD-N/ac.

Summary and Conclusions

Fertilization with $NaNO_3$ increased dry weight of cotton plants compared to fertilizaion with urea. The increase was mainly due to a 9.1% increase in leaf dry weight. Although these results correlate well with results from long term field experiments on the same Coastal Plain soil, economic considerations would probably override any benefits of increased growth resulting from applications of $NaNO_3$ in the field. The increased growth from $NaNO_3$ resulted in dilutions of nutrient element concentrations in leaf tissue.

Cotton is sensitive to DCD, as evidenced by foliar toxicity symptoms and reductions in plant growth. However, significant reductions in plant growth did not occur unless DCD exceeded that normally applied with recommended N rates on this sandy soil (10 lb/ac DCD-N in 100 lb/ac N). One effect of DCD is reduced uptake of Ca and Mg and an increase in P uptake.

Although the use of DCD to improve N efficiency of cotton grown on sandy soils offers potential benefits to growers, our preliminary results indicate the need for caution when applying this nitrification inhibitor. Phytotoxicity from concentrations of DCD > 10 lb DCD-N/ac in the root zone of cotton might negate any potential benefits derived from increased N efficiency gained through the inhibition of nitrification.

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Table 1. Effect of N source on growth of cotton plants harvested 67 days after emergence.

N Source	Dry wt. Roots	Stems	Leaves	Root fresh wt.	Leaf area	Squares + Blooms
	g				cm^2	Mean No./Plant
$NaNO_3$	10.56	15.19	13.76	70.30	1681	2.15
Urea	10.19	14.65	12.61	69.56	1592	1.80
$LSD_{0.05}$	1.19	0.71	0.69	5.11	92	0.26
0-N control	3.12	3.24	4.01	23.6	432	0

Table 2. Effect of DCD on growth of cotton plants harvested 67 days after emergence.

DCD-N (lb/ac)	Total Plant Dry wt.	Leaf Dry wt.	Stem Dry wt.	Root Fresh wt.
	g			
0	43.6	14.7	15.8	76.8
5	41.0	13.8	15.6	68.6
10	41.4	13.8	15.1	72.8
20	39.6	12.4	14.7	71.4
30	39.1	12.7	14.4	66.4
40	37.8	11.8	13.8	63.7
Regression Model[1]	L	L	L	L
R^2	0.55	0.47	0.60	0.25

[1]L = linear regression model; all models significant at 0.01 level.

Table 3. Effect of N source and DCD on nutrient concentrations of leaf + square tissue of cotton plants harvested 67 days after emergence.

N Source	N	P	K	Ca	Mg	Mn
	%					ppm
$NaNO_3$	1.40	0.19	0.99	1.46	0.33	49
Urea	1.40	0.24	1.09	1.45	0.30	60
$LSD_{0.05}$	ns	0.011	0.054	ns	0.013	2.9
DCD-N (lb/ac)						
0	1.32	0.18	0.93	1.61	0.35	59
5	1.34	0.20	0.98	1.62	0.35	60
10	1.34	0.20	0.97	1.51	0.32	55
20	1.41	0.23	1.08	1.41	0.30	54
30	1.48	0.25	1.10	1.26	0.29	48
40	1.53	0.24	1.18	1.33	0.28	49
$LSD_{0.05}$	0.07	0.020	0.094	0.089	0.022	5.1
0-N check	0.94	0.22	0.53	1.77	0.35	106

Table 5. Effect of N source and DCD on P uptake rate of cotton plants harvested 67 days after emergence.

N Source	DCD-N (lb/ac) 0	5	10	20	30	40	Mean
	μg/g fr. root/day						
$NaNO_3$	16.3	17.1	15.3	16.0	17.1	17.3	16.5
Urea	14.3	18.3	18.9	19.5	21.6	21.6	19.1
Mean	15.3	17.7	17.1	17.8	19.6	19.4	

N Source $LSD_{0.05}$ = 1.15

DCD $LSD_{0.05}$ = 1.98

N Source X DCD $LSD_{0.05}$ = 2.81

0-N check = 16.7

Table 4. Effect of N source and DCD on Ca and Mg uptake rates of cotton plants harvested 67 days after emergence.

N Source	Uptake Rate Ca	Mg
	- -µg/g fr. root/day- -	
$NaNO_3$	95.0	26.8
Urea	88.4	23.5
$LSD_{0.05}$	4.89	1.76
DCD-N (lb/ac)		
0	97.8	27.0
5	106.2	29.1
10	93.1	25.4
20	84.1	22.8
30	84.9	23.8
40	85.0	23.1
$LSD_{0.05}$	11.99	3.04
0-N check	86.9	25.3

FERTILIZATION OF COTTON UNDER REDUCED TILLAGE CONDITIONS

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Key Words: Gossypium hirsutum, Reduced tillage, Starter fertilizer, split application, sidedress, broadcast application, nitrogen, phosphorus, cotton lint, fiber quality

Abstract

The effects of starter fertilizer and other placement methods on yield and fiber quality of cotton grown under reduced and conventional tillage systems were studied in a three-year field experiment. Conventional tillage common to the region was compared with a reduced tillage system on a calcareous Orelia sandy clay loam located in the Coastal Bend region of southern Texas. Both reduced and conventional tillage were compared at fertilizer rates of 0-0-0, 40-40-0 and 60-60-0. Fertilizer placement combinations included: all knifed preplant, all broadcast and disc incorporated, 2/3 knifed preplant plus 1/3 starter, and 2/3 knifed preplant plus 1/3 sidedressed. Additional placement treatments included: pop-up fertilizer (13-13-0 placed with seed and 27-27-0 knifed preplant) and repeated annual placement of 40-40-0 and 60-60-0 in the same band as separate treatments with reduced tillage. Plant populations were generally unaffected by fertilizer rate and tillage systems. However, lowest plant populations were measured with pop-up fertilizer in two years of the three-year study. Lint yields and treatment response varied with years. Fertilizer response was limited to the initial 40-40-0 rate and generally was greatest when banded preplant in both reduced and conventional tillage. Band placement was superior to broadcast incorporated with reduced tillage in two years of the three-year study. Splitting fertilizer into preplant (2/3) and sidedress (1/3) had no beneficial effects on yields in the conventional tillage. With reduced tillage, substantial decreases in lint production were measured from similar side-dressing treatments under both suboptimal and above average rainfall conditions. No yield response was recorded to pop-up and starter fertilizers. Fiber strength was the only quality parameter affected by fertilizer rate and tillage.

Introduction

Interest in conservation tillage programs has increased substantially in many regions. This practice has been on a relatively slow increase in the South and Southwest for several years. Change to this alternative tillage system has been slow in South Texas due to warmer temperatures and a longer growing season for weeds and consequent greater use of chemical herbicides. On coarse textured soils, a carryover of chemicals can be a significant factor. Long range benefits in terms of soil erosion control and more immediate savings on capital investment in equipment and less fuel and labor have contributed to the interest in this alternate tillage system.

Research on conservation tillage in southern Texas has been conducted for several years (Matocha et al., 1980; Norden and Matocha, 1982; Salinas et al, 1981). However, the practice of minimized tillage raises questions concerning a possible need for modification in fertilization methodology. Decomposition and mineralization of crop residue and organic matter are dependent upon oxidation. Reduced tillage can result in decreased soil aeration and mineralization of organic matter. This in turn can affect the soils supply of available nutrients. Also, reduced and no-till systems have encouraged shallow bandings or broadcast applications of fertilizer nutrients. Previous research results have generally supported band applications of fertilizer nutrients over broadcast applications (Ghodrati, 1983; Welch et al. 1966; Lamond and Mayer, 1983; and Sleight et al., 1984).

Nutrient placement in respect to the seed has received considerable attention in the past several years (Alessi and Power, 1980; Touchton and Karim, 1986). Weather conditions can contribute to the relative response to starter fertilizer which is usually a function of soil nutrient supply, amount of nutrient applied, and climatic conditions for a given season. The purpose of this study was to compare the effects of fertilizer rates and placement methods on lint production and fiber quality of cotton grown under conservation and conventional tillage systems; and, also to evaluate the interactive effects of starter fertilizer and tillage systems.

Materials and Methods

A field study was conducted at the Texas A&M University Agricultural Research & Extension Center Farm at Corpus Christi, Texas in 1983, 1985 and 1986. In the initial year, the study was located on a Victoria c (Typic Pellusterts). Chemical analyses of soil from the surface 6 inches showed pH 7.9 (2:1water-soil), organic matter 1.8%, NH_4OAc-EDTA extractable P at 18 lb ac^{-1}, exchangeable K at 746 lb ac^{-1}, exchangeable Ca at 11,800 lb ac^{-1}, and exchangeable Mg at 854 lb ac^{-1}. According to soil test criteria, the P was low and the exchangeable cations were in the high range. The study was moved to an Orelia scl (Typic Ochraqualfs) for the second and third years of the study. This soil tested medium in extractable P (24 lb ac^{-1}), high in exchangeable K, Ca and Mg. The test area had been cropped to cotton and grain sorghum prior to start of the study.

Treatment variables included two types of preplant tillage, fertilizer rates, starter fertilizer, pop-up fertilizer, and fertilizer placements. Tillage systems were considered in the main plots while fertilizer rates and placement treatments were compared in split plots. A reduced tillage system developed earlier at the Center Farm which involved five tillage trips per year was compared with conventional tillage which involved 11-12 tillage operations. The conventional system included the following operations: shred, disc, bed, disc, rebed, rerun beds(2-3X), plant and cultivate(2X). The conventional bedder sweep system tilled the soil to a depth of six inches during the primary tillage operations while the reduced till system manipulated the soil with minimum of particle movement to a depth of 4 inches. The reduced till system involved five tillage operations (sweep plow middles, root plow beds, rerun middles, fertilize, plant and cultivate (1X). Tillage treatments were compared in major plots which measured 80 feet in length and 76 feet in width. Row spacing was 38 inches which permitted 24 rows per main plot. Fertility treatments(split plots) were 40 feet in length and 12.7 feet (4 rows) in width. All fertilizer rate and placement treatments were randomized within main plots which in turn were randomized within each replication. All treatments were studied in four replicates.

Fertilizer sources were fluids, ammonium polyphosphate (APP, 10-34-0) and urea ammonium nitrate (UAN, 32-0-0). Quantities of both materials were applied to give the following ratios (N-P-K): 0-0-0, 40-40-0 and 60-60-0. The 40-40-0 was approximately the rate prescribed by soil test recommendations.